



TECHNICAL PAPER

STANDARDIZED UXO DEMONSTRATION SITES

US ARMY CORPS OF ENGINEERS - ENGINEERING RESEARCH AND DEVELOPMENT CENTER: TM-4 MAGNETOMETER/SLING

- OPEN FIELD SCORING RECORD No. 364



The TM-4 Magnetometer/Sling is shown as demonstrated by USACE Engineering Research and Development Center at Yuma Proving Ground, Arizona.

The TM-4 Magnetometer/Sling
was demonstrated by the US Army Corps of Engineers (USACE) Engineering Research and Development Center (ERDC) at the Yuma Proving Ground Standardized Demonstration Site's Open Field Area. This Technical Paper contains the results of that demonstration. This Technical Paper is a reference document only and does not serve as an endorsement of the demonstrator's product by the US Army or the Standardized UXO Technology Sites Program.

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Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground, Maryland, and Yuma Proving Ground, Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the US Army Environmental Center (USAEC). The US Army Aberdeen Test Center and the US Army Corps of Engineers Engineering Research and Development Center provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, and the Army Environmental Quality Technology Program.

DEMONSTRATOR'S SYSTEM AND DATA PROCESSING DESCRIPTION

The TM-4 is a sophisticated magnetometer system that was developed by G-Tek Australia and its predecessor, the Geophysical Research Institute, over a period of 15 years. The TM-4 has been designed for deployment from a number of terrestrial, marine, and airborne survey platforms and can be configured to include differential Global Positioning Systems for navigation, as well as digital compensation for heading, pitch, and roll interference from a survey vehicle. It consists of a data acquisition and detector control system and one or more optically-pumped magnetic sensors. The individual components of the system and the field operation are described in the following paragraphs.

The TM-4 controller is a 32-bit computer based on a 12.5 MHz Motorola 68030 CPU and a Motorola 68331 floating-point coprocessor. The standard memory of 6 MB in the TM-4 has the capacity for over a million data points. The data acquisition software is based on a proprietary, preemptive multi-tasking operating system designed specifically for high-speed data acquisition.

In hand-held operation along straight grid lines, automatic data acquisition was controlled by an in-built cotton thread odometer that provided an electronic pulse to the controller at 0.05 m intervals. The data logging system was interactive and permitted the operator to permanently record notes related to geological observations of significance and cultural features such as fences or scrap metal. At the end of a survey the information facilitates the automatic generation of geological and/or cultural feature maps that often provides an invaluable aid to data interpretation.

Optically-pumped, alkali vapor magnetic sensors were developed based on helium and a number of alkali metal vapors that included potassium, rubidium, and cesium. However, the most common commercially available sensors use cesium. The sensors used with the TM-4 include the G-822A (EG&G Geometrics, 1992) and the CS-2 (Scintrex, 1993a) cesium vapor magnetic sensors.

At Yuma, the positioning for the magnetometer was provided by a Trimble 5700 RTK Global Positioning System (GPS). This system is the state of the art in GPS positioning and has consistently enabled G-Tek to achieve positional accuracies at the centimeter level.

The TM-4 was operated as a two-person system. The person in front carries the sensor frame, ensuring that a constant height and yaw angle is maintained throughout the survey. They are connected to the second person controlling the data-acquisition system by an umbilical cord. Where practical, the TM-4 will be operated in quad-sensor configuration with four magnetometers separated by one foot distance. If the terrain conditions are sufficiently adverse, the frame can be reduced in size and operated as a dual-sensor system.

Magnetometer data was collected along parallel transects separated by 1 meter. This will cause adjacent lines to overlap slightly and will ensure that even if the operator deviates from the intended path, full coverage should still be achieved. The TM-4 continuously records magnetometer data at a sample rate of 10 Hz. With the intended maximum walking speed of 1 m/s, this will ensure that the along-line sampling rate will be 10 cm at most. To ensure that the sensors remain on track as much as possible, survey chains and traffic cones will be used to mark the beginning and end of each line (and may also be placed at 25 m intervals within the survey area).

During the survey a proton-procession magnetometer will be positioned in a fixed location and will record magnetic field measurements once every five seconds. This will allow temporal variations in magnetic fields to be eliminated from the survey data.

PERFORMANCE SUMMARY

Results for the open field test, broken out by size, depth, and nonstandard ordnance, are presented below. Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range. The results are relative to the number of ordnances emplaced. Depth is measured from the geometric center of anomalies.

The response stage results are derived from the list of anomalies above the demonstrator-provided noise level.

The results for the discrimination stage are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence limit on probability of detection and probability of false positives was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

The overall ground truth is composed of ferrous and non-ferrous anomalies. Due to limitations of the magnetometer, the non-ferrous items cannot be detected. Therefore, the summary presented in the "Ferrous Only" table exhibits results based on the subset of the ground truth that is solely the ferrous anomalies. The second table exhibits results based on the full ground truth. The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.

SUMMARY OF OPEN FIELD RESULTS (FERROUS ONLY)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P _d	0.40	0.40	0.40	0.30	0.45	0.70	0.40	0.55	0.25
P _d Low 90% Conf	0.39	0.38	0.36	0.24	0.38	0.63	0.34	0.47	0.16
P _d Upper 90% Conf	0.45	0.47	0.46	0.32	0.49	0.76	0.42	0.58	0.36
P _{fa}	0.45	-	-	-	-	-	0.50	0.40	0.10
P _{fa} Low 90% Conf	0.45	-	-	-	-	-	0.47	0.39	0.01
P _{fa} Upper 90% Conf	0.49	-	-	-	-	-	0.51	0.46	0.34
BAR	0.15	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P _d	0.40	0.40	0.40	0.25	0.40	0.70	0.35	0.50	0.25
P _d Low 90% Conf	0.37	0.37	0.35	0.22	0.37	0.63	0.32	0.46	0.16
P _d Upper 90% Conf	0.44	0.46	0.44	0.30	0.48	0.76	0.40	0.58	0.36
P _{fa}	0.45	-	-	-	-	-	0.50	0.40	0.10
P _{fa} Low 90% Conf	0.45	-	-	-	-	-	0.46	0.39	0.01
P _{fa} Upper 90% Conf	0.48	-	-	-	-	-	0.50	0.46	0.34
BAR	0.15	-	-	-	-	-	-	-	-

Response stage noise level: 18.00

Recommended discrimination stage threshold: -1,460.00

SUMMARY OF OPEN FIELD RESULTS (FULL GROUND TRUTH)

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P _d	0.35	0.35	0.40	0.20	0.45	0.70	0.30	0.45	0.25
P _d Low 90% Conf	0.33	0.30	0.35	0.17	0.38	0.63	0.29	0.41	0.16
P _d Upper 90% Conf	0.39	0.37	0.44	0.24	0.49	0.76	0.36	0.51	0.35
P _{fa}	0.45	-	-	-	-	-	0.50	0.40	0.10
P _{fa} Low 90% Conf	0.45	-	-	-	-	-	0.47	0.39	0.01
P _{fa} Upper 90% Conf	0.49	-	-	-	-	-	0.51	0.46	0.34
BAR	0.15	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P _d	0.35	0.35	0.40	0.20	0.40	0.70	0.30	0.45	0.25
P _d Low 90% Conf	0.32	0.29	0.33	0.16	0.37	0.63	0.27	0.40	0.16
P _d Upper 90% Conf	0.38	0.36	0.42	0.22	0.48	0.76	0.34	0.50	0.35
P _{fa}	0.45	-	-	-	-	-	0.50	0.40	0.10
P _{fa} Low 90% Conf	0.45	-	-	-	-	-	0.46	0.39	0.01
P _{fa} Upper 90% Conf	0.48	-	-	-	-	-	0.50	0.46	0.34
BAR	0.15	-	-	-	-	-	-	-	-

Response stage noise level: 18.00

Recommended discrimination stage threshold: -1,460.00

Note: The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.

